Design And Development Of Heat Exchanger For Solar Thermal Energy Storage

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Abstract- *The use of a latent heat storage system using phase change materials (PCMs) is an effective way to store solar thermal energy. Latent heat storage system is an isothermal nature of storing energy and has advantages of high-energy storage density. The present study includes thermal reliability of Benzamide and Sebacic acid as phase change materials (PCMs). The selected phase change materials were Benzamide and Sebacic acid with melting temperatures between 1270C - 1340C. Latent heat storage capacity and phase transition temperature of the PCMs were determined by Differential Scanning Calorimetry(DSC) technique after repeated thermal cycles such as 0th ,100th,200th,300th,400th,500th,600th.700th,800th,900th,1000 th. The present work also comprises the investigation of corrosion resistance of some construction materials to the benzamide and sebacic acid over a long period. The containment materials tested were stainless steel (SS), aluminium (Al), copper (Cu). Gravimetric analysis as mass loss(mg/cm2), corrosion rate(mg/day) and microscopic were performed for corrosion tests after thermal cycles. In addition to the thermal reliability and corrosion analysis, suitable heat exchanger was also designed and fabricated. DSC measurements showed that Benzamide and Sebacic acid investigated as PCMs have a good thermal reliability as a function of latent heat and phase transition temperature range for an actual thermal energy storage utility.*

Keywords- Benzamide, Sebacic acid, Stainless steel, Aluminium, Copper.

I. INTRODUCTION

ENERGY SCENARIO

The continuous increase in the level of greenhouse gas emissions and the increase in fuel prices are the main driving forces behind efforts to more effectively utilize various sources of renewable energy. In many parts of the world, direct solar radiation is considered to be one of the most prospective sources of energy. The scientists all over the world are in search of new and renewable energy sources. One of the options is to develop energy storage devices, which are as important as developing new sources of energy. The storage of energy in suitable forms, which can conventionally be converted into the required form, is a present day challenge to the technologists. Energy storage not only reduces the mismatch between supply and demand but also improves the performance and reliability of energy systems and plays an important role in conserving the energy.

It leads to saving of premium fuels and makes the system more cost effective by reducing the wastage of energy and capital cost. For example, storage would improve the performance of a power generation plant by load levelling and higher efficiency would lead to energy conservation and lesser generation cost. One of prospective techniques of storing thermal energy is the application of phase change materials (PCMs).

The use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy and has the advantages of high-energy storage density and the isothermal nature of the storage process. PCMs have been widely used in latent heat thermal storage systems for heat pumps, solar engineering, and spacecraft thermal control applications. The uses of PCMs for heating and cooling applications for buildings have been investigated within the past decade. There are large numbers of PCMs that melt and solidify at a wide range of temperatures, making them attractive in a number of applications.

II. LITERATURE REVIEW

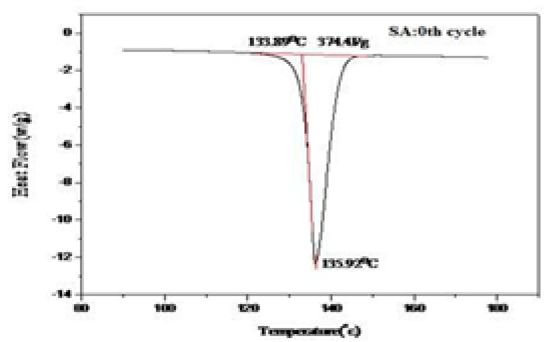
Sharma, A. et al (2009), established that the use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy and has the advantages of high-energy storage density and the isothermal nature of the storage process. PCMs have been widely used in latent heat thermal storage systems for heat pumps, solar engineering, and spacecraft thermal control applications. There are large numbers of PCMs that melt and solidify at a wide range of temperatures, making them attractive in a number of applications.

Anant Shukla (2008), Thermal cycling tests were performed to check the stability in thermal energy storage systems on some selected organic and inorganic phase change materials (PCMs). The possibility of using these PCMs in thermal energy storage systems were examined on the basis of thermal, chemical and kinetic criteria. Organic and inorganic PCMs were selected to check their thermal stability. Inorganic PCMs were not found suitable after some cycles while thermal cycling for organic PCMs were undertaken up to 1000 thermal cycles and has shown a gradual change in melting temperature and latent heat of fusion. The PCMs were then checked with differential scanning calorimeter (DSC) for their latent heat storage capacity and melting temperature change.

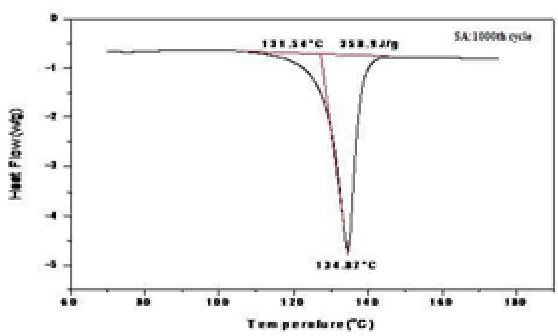
III. RESULTS AND DISCUSSSION

The accelerated thermal cycling test was conducted on the hot plate which was maintained at a constant temperature of 160oC shown in figure 14. This process is repeated several times up to 1000 cycles sample is taken out from the container for every 100 cycles that is 0, 100, 200, 300, 400, 500, 600, 700, 800, 900,1000 cycle.

The time taken for melting process is about 10 minutes and for cooling process it takes about 22 minutes. The thermo-physical properties such as melting temperature and latent heat of fusion of these materials between 0-1000 cycles were measured using DSC and the obtained results.



DSC curve for 0th cycle

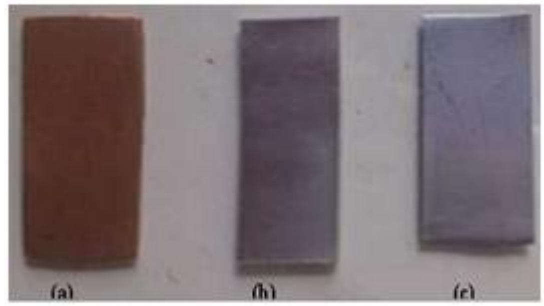


DSC curve for 1000th cycle

CORROSION ANALYSIS SEBACIC ACID

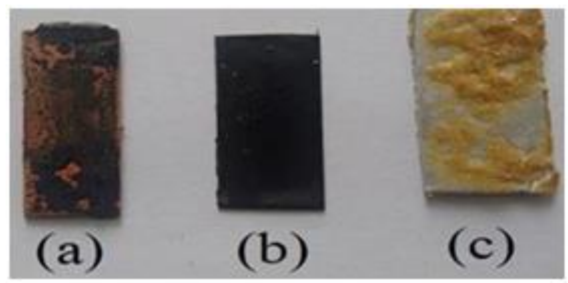
The corrosion analysis is performed with Stainless steel, Aluminium, Copper inserted in Sebacic acid for 500 cycles to analyse the corrosion rate.

Before cycling :



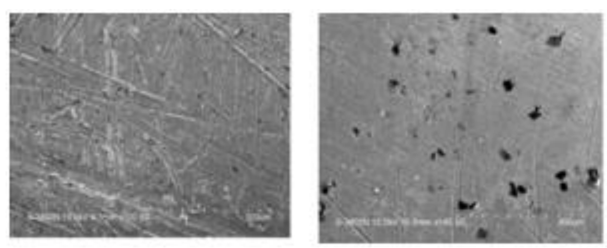
(a)Copper (b) Stainless steel(c) Aluminium

After cycling :



(a)Copper (b) Stainless steel (c) Aluminium

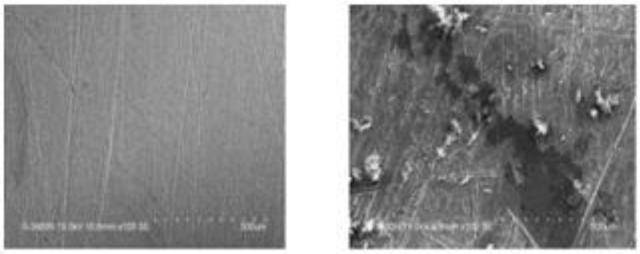
Corrosion rate for different materials in sebacic acid



(a) (b)

SEM image for aluminium (a) Before cycling

(b)After 500 cycle



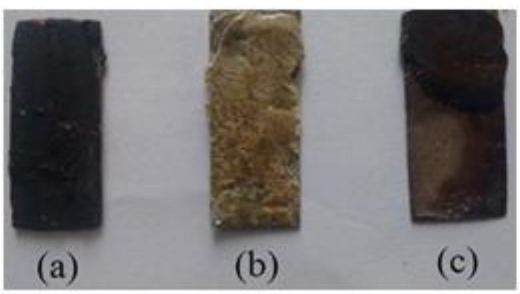
(a) (b)

SEM image for copper (a) Before cycling (b)After 500 cycles

DSC analysis of Benzamide Before cycling

(a)Copper (b)Stainless steel (c) Aluminium

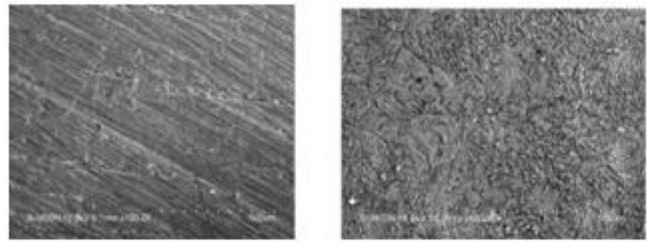
After cycling



(a)Copper (b)Stainless steel (c) Aluminium

As the number of cycle increases there will be slight changes in the melting temperature and latent heat of fusion of the sebacic acid. The variation are less so it is consider to be selected PCM is thermally reliable. The selected PCM benzamide shows only very small variations in the melting temperature and latent heat of fusion .

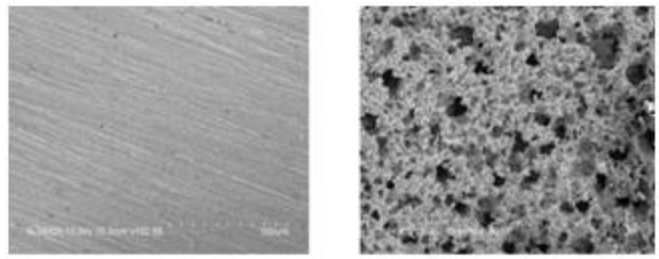
Corrosion rate for different materials in Benzamide



(a) (b)

SEM image for stainless steel (a)Before cycling

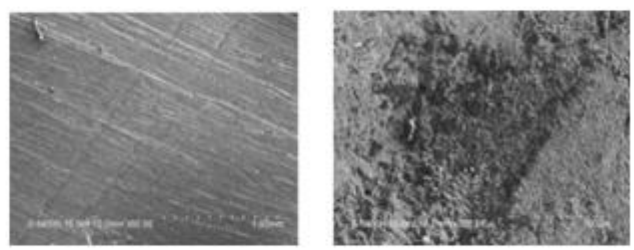
(b)After 500 cycles



(a) (b)

SEM image for Aluminium (a)Before cycling

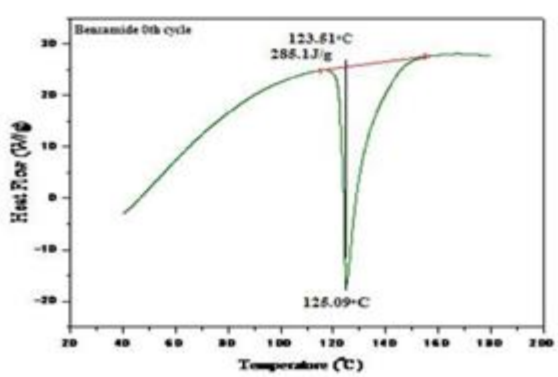
(b) After 500 cycles



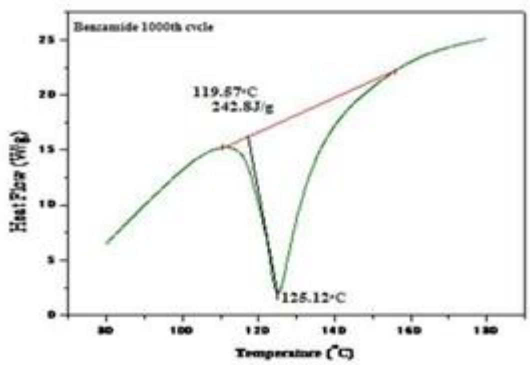
(a) (b)

SEM image for Copper (a)Before cycling

(b) After 500 cycles



DSC curve for 0th cycle



DSC curve for 1000th cycle

Performance evaluation of rectangular shell and tube heat exchanger

Performance evaluation of rectangular shell and tube heat exchanger is studied . the Variation of energy release and surface temperature of heat exchanger with respect to solar radiation.

The Rectangular shell and tube heat exchanger is studied to test the PCM. Temperature on the surface of the heat exchanger was measured to determine the maximum temperature absorbed without load conditions and also the amount of energy released from the heat exchanger. The above graphs Figure.49 and Figure 50, shows the variation of surface temperature and energy released with respect to the time and solar radiation. The maximum surface temperature and energy absorbed from the heat exchanger are 62.5oC.

IV. CONCLUSION

The objective of this study is to determine the thermal reliability and corrosion analysis of benzamide and sebacic acid as a latent heat energy storage phase change material with respect to various numbers of thermal charging and discharging cycles. In addition to the thermal studies a suitable shell and tube heat exchanger has been designed and fabricated. The melting temperature and latent heat of fusion for Benzamide at 0th cycle is 123.510C and 285.1 J/g and for 1000th cycle is found to be 119.570C and 242.8 J/g . Similarly the melting temperature and latent heat of fusion for sebacic acid at 0th cycle is 133.890C and 374.4 J/g and for 1000th cycle it is 131.540C and 358.9 J/g. From the gravimetric and microscopic analysis, it can be concluded that Stainless steel(SS) and aluminium(Al) metals are essentially compatible with Benzamide and sebacic acid as heat exchanger material whereas,

Copper(Cu) is less preferentially recommended as storage container material. The DSC thermograms, shows that Benzamide and Sebacic acid have a good thermal reliability as a function of latent heat and phase transition temperature range for medium temperature applications.

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